

## Reviewer Review Report

Technical Publication: Incorporation of Climatic Indicators in SFWMD Planning and Operations

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### *Reviewer Section*

Reviewer's Name: Eric F Wood

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1. *Has the District adequately addressed the long-term wet and dry cycles in modeling for a) facility planning, and b) operational planning. If not, what standard engineering practices can District modelers follow to address climate variability due to indicators such as AMO.*

The District must be commended for taking into consideration low-frequency climate variability related to climate models like ENSO, PDO and AMO. Overall they have worked hard to understand the effects of these climate modes on the weather and climate of the District, and resulting impacts on rainfall and runoff throughout the system.

What has been done well, and for the most part completely, is consider the historical record and evaluated changes in precipitation patterns with the various climate modes. They make a fairly compelling argument that the 1965 – 2000 (and soon to 2005) record is adequate for facility planning, they carefully investigated the proportion of the record that falls within the various climate modes, and test statistically (Appendix A) the observed shifts. While I have some concerns regarding some details overall I feel the analysis is adequate for facility planning *assuming that the climate doesn't change*. One concern with the statistical tests is their focus on shifts in the mean rainfall whereas change in variability may be more important to the system. It is well known that reservoir sizing is sensitive to inflow variability, and Figure 1 of Appendix A, shows quite different variability in modes AOM1, AOM2, etc. In my reading of the report, it was unclear the extent of quantitative statistical analyses related to precipitation variability, and perhaps this areas needs to be strengthened and its impact on storage reliability assessed.

This reviewer feels the report doesn't adequately consider how projections of future climate may affect SFWMD facilities and their performance. I recognize that this is a complicated problem, but given your identified strong teleconnections to climate modes whose strength, frequency and duration may change significantly over the next 50-75 years (the SFWMD planning horizon stated in the report), I feel more work and attention is needed. I think SFWMD needs to develop a program that uses the most recent suite of IPCC climate model runs, including the model runs of the 20<sup>th</sup> Century climate, to carry out an assessment of how precipitation and temperature, both seasonally and annually, may change. The work will have to include procedures to downscale and bias correct the climate models, detailed analysis of projected changes in atmospheric flows that affect changes in weather patterns,

and an analysis of the adequacy that these models capture well ENSO, PDO and AMO climate modes, and what are the projected changes in these modes.

With regard to operational planning, I think the adaptive management approach is very appropriate. I think that the District is under-utilizing the potential of dynamical seasonal climate forecasts being developed by NOAA. These forecasts, which go out to 9 months, need to be adapted for hydrological applications through downscaling and bias corrections, but NOAA is supporting research and applications in this area. The forecasts consist of a number of potential 'realizations' that can be used in the current SFWMD 'position analysis' approach. South Florida is one area of the country where it is believed these forecast models have skill, but this needs to be confirmed through detailed hindcast studies. I would urge SFWMD to consider these dynamical forecasts as providing important information that can help operational planning. The reviewer can help SFWMD identify sources of these forecast products if they so desire.

It was unclear in the historical precipitation analysis the impact of hurricanes. Have the studies separated out precipitation related to hurricanes and how this affects facility planning and operations? Would it be useful to have a separate distribution and statistical analysis for non-hurricane precipitation and hurricane impacts? Except for a brief reference to Atlantic tropical storms on page 9, the report really didn't address this issue. Given that tropical storm frequency and intensity may increase over the next 50 years, a specific analysis may be useful for SFWMD.

2. *Is there compelling evidence that the volume of inflows to Lake Okeechobee will be as much as double during wetter cycle as they were in the dry cycle? In the current modeling efforts, has the District adequately addressed the variability of inflows into Lake Okeechobee?*

Figure 5 in the report provides a mixed message with regard to inflows during the dry cycle relative to the wet cycle, as do the results in Appendix A. Further, it was unclear from Appendix A whether the statistical *t*-tests considered what appears to be differences in the inflow distribution variances in wet and dry cycles. After carefully reading the report, I don't think the presented results are comprehensive enough to answer this question with confidence regarding the sensitivity of the inflows to Lake Okeechobee to wet and dry climate cycles.

More in depth statistical analysis could be carried out. Some examples include: (i) Non-parametric statistical tests testing whether the median or variability of the inflow distributions differ during wet and dry cycles (e.g. Wilcoxon rank sum for location; and Kruskal-Wallis test for variance.) (ii) Computing the *statistical power* of the tests shown in Appendix A. The tables showing statistical significance would be enhanced if the *statistical power* of the tests were also provided. I suspect that the type II errors could be quite large. (iii) Understanding better the effect of the sample sizes on the results through careful design and analysis of the statistical tests, and what shift in mean and variance of the inflows from dry and wet cycles would provide of high confidence and power. It seems to me that for specified changes, it's possible to calculate the sample sizes needed to meet specified statistical confidence and power. (iv) Investigate the use of statistical resampling (boot

strapping) to generate longer or equivalent records that could be used to test the robustness of the results presented in Appendix A.

Regarding modeling efforts to address the variability of inflows into Lake Okeechobee, the report addresses this in a quite comprehensive manner. It seems to me that simulating the system using the SFWMM, coupled with a land surface hydrology model (it appears that SFWMM requires local basin runoff and irrigation as inputs) could be done for the total period of the PRISM precipitation record (111 years.) They talk that the current period for simulation is from 1965, and that this covers an adequate range of conditions. While this may be true, the report states that the reason for the 48% change in inflow during dry periods is still unresolved (pg 13). Through modeling they may be able to gain insight as to the reasons for the significant change, or to eliminate particular causes that they list on page 13. Going forward into a changing climate, it behooves SFWMD to gain as much insight into the physical mechanisms that control the hydrologic sensitivity of various portions of their system.

As an aside, it was unclear how figure 11 was constructed. It appears that an arbitrary +/- 10% was added to the rainfall. The result seems to show that even for this simple case reduced rainfall increased inflow variability. What about changes in rainfall variability, which may increase this difference?

3. *Does the modeling approach used by the District for both CERP and WSE schedule design meet requirements of standard engineering and design practices. If not, what additional steps should the District take to improve modeling for the applied purposes?*

From the information provided in the report, I feel that the SFWMM model is an effective tool for assessing management decisions. I feel that the current approach on the use of climate outlooks, as described on pages 22 – 23, is somewhat dated and doesn't utilize the latest developments in dynamical seasonal forecasting and ensemble prediction being offered by NOAA. The statement "SFWMD climate outlook methodology has been peer-reviewed" to be somewhat of an overstatement, based on the three given citations. None are in a peer-reviewed climate-focused journal, which is the standard for such a statement.

It is unclear from the report how the District takes these outlooks and converts them into future realizations, except by stochastic generation of future rainfall. It is unclear from the report whether this approach adds skill, which can be assessed through careful retrospective studies. Most of the work (and references) on "position analysis" (pg 23) is a little dated. It's not incorrect, but the approach can be strengthened and SFWMD needs to test the potential of ensemble-based dynamical seasonal forecasts. Work is required to take the forecasts from NOAA (CPC) and correctly downscale to the District level, but the 20+ years of 'hindcasts' provide an adequate modeling database to determine the value of such forecasts. It is my opinion that this is the correct direction for the District, and these forecasts will offer the District an ensemble (set of future realizations) of future outlooks providing measures of uncertainty. From my reading of the report, current modeling approaches (SFWMM, adaptive control, etc.) could be easily use such climate forecasts.

A feel the adaptive management approach underpinning WSE scheduling is a very effective modeling approach, and I applaud the District for developing this framework. Again, the ensemble seasonal forecasting approach would fit well into this framework.

4. *Are the steps being taken in the adaptive management/modeling approach used by the District adequate to address the uncertainties in climate predictions and to assimilate new information?*

The report provides insufficient information to fully address this question. My sense from reviewing the report is as follows: I think the adaptive management modeling approach is an adequate framework for considering uncertainties in climate predictions, but the uncertainties are probably not being estimated correctly. To determine this, the retrospective forecasts need to be compared to what actually happened. In most (almost all) seasonal forecasts systems where a set of future traces (ensembles) are generated, the actual outcome is usually at the top or bottom of the ensembles, suggesting that the future traces (ensembles) underestimate the future uncertainty. If the uncertainties are not being estimated correctly, then the possible range of responses can not be generated.

The report isn't sufficiently clear how new information is assimilated into the adaptive management model, or how often.

5. *Except for basic research approaches, are there other facility planning options that the District should consider to address the possibility of a continues wetter cycle?*

Not that I could identify from reviewing the report.

6. *Are the data and models used by the District appropriate (reasonable and adequate) for their intended applications?*

Issues raised in this question have been addressed in earlier responses. As a summary, I feel that the data is probably sufficient, even though the use of the PRISM precipitation data set and statistical resampling offer opportunities to test the robustness of results presented in the report, which are based on a more limited time series. The report presents material arguing that the current database should be adequate, and these arguments are quite compelling. Regarding data on seasonal forecasts, I think better data/forecasts can be used than the 'climate outlook', whose source I couldn't ascertain from the report.

The management model (SFWMM) and the adaptive management approach WSE appear adequate. I think the 'position analysis' technique can be strengthened, specifically by restructuring how, or on what basis, the future traces are created.

*Please list any issues/concerns which you feel MUST be addressed before this document can be published.*

1. The report doesn't offer information on the skill gained by using climate outlooks, either in the prediction of precipitation/temperature or in improved management. I think this needs to be addressed, especially since the report focuses on climate indicators.
2. The report needs to include a statement (and study plans) to evaluate how new climate change projections may impact facility planning and operation of the SFWMD. This would include changes in both 'normal' weather and tropical hurricanes.
3. The report needs to discuss the potential use of dynamical seasonal forecasts in the adaptive management of the system. The report need not resolve whether such forecasts would be useful/skillful, but I think the report should recognize that this work needs to be carried out to evaluate their usefulness/skillfulness.
4. The reports recommendations are very generic, and it is difficult to understand how they will be implemented.

*Please list areas of the publication that were NOT covered by your review (e.g. references, meeting journal format requirements, adherence to District standards..)*

The areas not covered by my review were mostly related to formatting of the report. I also didn't check the references for completeness. I don't know the Districts standards related to reports, so I can't comment on this

*Please list any typos or minor format issues that must be corrected.*

1. Figures 6, 7 and 8. The captions appear incorrect. For example, both 6 and 7 refer to the Kissimmee basin but figure 7 is for the Upper Kissimmee basin. Also the text says figure 7 is the runoff coefficient (for the Kissimmee basin) but it's the Upper Kissimmee basin discharge at S65.
2. On page 27 (4<sup>th</sup> paragraph): I believe "Figure 6" should say "Figure 5".

I have read this technical publication and have provided a careful, objective professional review.

Signature: \_\_\_\_\_ Date: \_\_\_\_\_